POZNAŃ UNIVERSITY OF MEDICAL SCIENCES
Department of Biophysics

Collegium Chemicum
6 Grunwaldzka Street
60-780 Poznań

BIOPHYSICS

A Guide for the 1-year Students of 5-year DDS Program 2019-2020

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Competency Based Curriculum

Upon completing the course the student should:

be competent at:

- graphical analysis and presentation of experimental results as well as estimation of the errors of measurements
- estimation and measurements of physical quantities such as:
  - half-value layer and linear attenuation coefficient
  - diffusion coefficient
  - electrode potential
  - surface tension
- description of viscoelastic properties of non-stimulated muscles
- solving problems of static equilibrium applied to muscles and bones
- description of thermal, mechanical and rheological properties of solids and fluids
- description and interpretation of physical properties of sound waves as determinants of physiological perception

have knowledge of the:

- solute and water movement through membranes, the movement of charged particles through membranes and the accompanying phenomena of creation of electric signals (resting and action potentials) and related electric activity of the human body
- functioning of the human circulatory system: flow of blood in the human circulatory system, based on the laws of flow of fluids
- functioning of the auditory system and sound perception mechanism
- functioning of the visual system, visual defects and their correction
- performance of skeletal muscles
- processes of heat transfer and exchange in the context of the human thermoregulation
- basic mechanical and thermal properties of solids in contexts of dental materials
- adhesion and cohesion

be familiar with:

- principles of modern techniques of visualization of human bodies using X-rays including the X-ray computed tomography, single photon computet tomography (SPCT) and postron emission tomography (PET)
- potential hazards and benefits resulting from the exposure of the human body to ultraviolet, visual and infrared radiation
- properties of the laser light
- measurements of dimensions of small objects by microscope
- principles of photometry

SYLLABUS

The course consists of 55 hours in the fall semester.
There are 8 lectures (12 hours), 9 laboratory classes (27 hours) and 6 seminar classes (16 hours)

LECTURES

Lecture attendance is mandatory.
Lectures are given in Coll. Stomatologicum, room 202, on Tuesdays from 16:05 to 17:15

LIST OF LECTURE TOPICS

1. Biophysics of the circulatory system

15.10.2019

1. Viscosity and viscosity of blood.
2. Types of fluid flow: the turbulent and laminar flow.
3. Laws of fluid flow: the law of continuity, the Hagen-Poiseuille law and Bernoulli's principle.
4. Arrangement of blood vessels and the vascular resistance.

2. Physical basis of trans-membrane transport of solutes and water

22.10.2019

1. Thermodynamic stimuli of trans-membrane transport, the transport categories.
2. Diffusion and dialysis: Fick's first law of diffusion, diffusion coefficient, the Einstein-Smoluchowski equation, diffusive permeability of cellular membranes.
3. Osmosis: osmotic pressure, van't Hoff's equation, isotonic, hypotonic and hypertonic solutions
4. Filtration and ultra-filtration.
5. Trans-capillary exchange of fluids – the Starling hypothesis.

3. Biophysics of muscles

29.10.2019

1. Types of muscle contraction (characteristic patterns).
2. Isotonic contraction - the physiological relationships:
   - velocity of contraction versus load - Hill's equation
   - amount of shortening versus load
   - muscle's power versus force developed
3. Isometric contraction: force - length relationship, passive and active component of the muscle force.
4. Elements of biomechanics: lever action of muscles and bones.

4. Heat exchange and thermoregulation

05.11.2019

1. The first law of thermodynamics: internal energy, enthalpy, the Hess law; the metabolic rate.
2. Mechanisms of heat exchange in the control of human body temperature: radiation, evaporation, convection, and conduction.

5. Physical properties of dental materials – part I

12.11.2019

1. Mechanical properties.
2. Rheological properties.
3. Thermal properties.
4. Adhesion.

6. Physical properties of dental materials – part II

19.11.2019

7. X-rays in medical diagnostics

26.11.2019

1. Generation of X-rays.
2. Properties of X-rays and control of their parameters.
3. Focal spot, resolution, magnification and contrast in X-ray radiography
4. Principles of attenuation of X-rays: the Lambert law, filtration and beam hardening, the K-edge of absorption and contrast media.
5. Principles of the X-ray computed tomography.

8. Non ionising radiation in medicine

03.12.2019

1. Interaction of light with matter; energy level diagrams: absorption and emission spectra; luminescence and fluorescence.
2. Absorption of light in tissues: the Lambert law, penetration depth, tissue optical window.
3. Properties of laser light
4. Thermal and non thermal effects - application in dentistry.
5. Light hardening.

Reference textbooks:

General reading:

1. Physics of the body, J.R.Cameron, J.G.Skofronick, R.M.Grant, Medical Physics Publishing, Madisson, Wisconsin, 1992, ISBN 0-944838-24-3
2. Introduction to physics in modern medicine, Susan Amador Kane, Taylor & Francis, London, New York, 2003, ISBN 0-415-30171-8 (pbk), ISBN 0-415-29963-2 (hbk)

Supplementary reading:

1. Introduction to Dental Materials - second edition, Richard van Noort, Elseviere Science, 2002, ISBN 0-7234-3215-5
2. Physics in Biology and Medicine - second edition, Paul Davidovits, Elseviere Science (USA), 2001, ISBN 0-12-204840-7

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LABORATORY CLASSES

Laboratory classes are held at the Department of Biophysics, 6 Grunwaldzka Street (Collegium Chemicum building), according to the schedule. Before the laboratory classes you are allocated to laboratory groups. You work in two-person teams.

We would expect all students to obtain and use a copy of:

Laboratory Exercises in Biophysics, edited by Marek Tuliszka, Poznań 2008, Wydawnictwo Naukowe Uniwersytetu Medycznego im. Karola Marcinkowskiego w Poznaniu, ISBN: 978-83-7597-012-8.

You are expected to be well prepared theoretically on the basis of the material from the suggested laboratory textbook.

Attendance at laboratory classes is obligatory. In case of non-attendance due to illness or other personal reasons, students are advised to make up for the missed classes following the coordinator's instructions.

Students are obliged to be on time. When coming more than 15 minutes late students are not allowed to take part in classes.

Below there is the list of problems necessary for students to be acquainted with before attending each laboratory class.

THE LIST OF PROBLEMS FOR THE LABORATORY CLASSES

IMPORTANT: NUMBERS IN BRACKETS ARE THE NUMBERS OF CHAPTERS IN THE LABORATORY TEXTBOOK: *Laboratory Exercises in Biophysics*, G: – CORRESPONDING CHAPTERS IN DOUGLAS C. GIANCOLI, PHYSICS - PRINCIPLES WITH APPLICATIONS 7TH EDITION (ON-LINE VERSION AVAILABLE).

1. **INTRODUCTORY CLASS: PRACTICAL ASPECTS OF PHYSICAL MEASUREMENTS (1)**
   Discussion of errors of measurements. Sample calculus based on chosen examples: the mean and maximum error - idea of standard deviation, errors of combined quantities. Graphical representation of experimental results and experimental errors.

2. **DIFFUSION (9); G: 13-13**
   The phenomenon of diffusion. The Fick law of diffusion. Concentration gradient. Diffusion coefficient (diffusion constant). Semi-permeable membranes and selectively permeable membranes. Membrane permeability and the permeability constant. The Einstein-Smoluchowski equation. Determination of the coefficient of the diffusion and the membrane permeability.

3. **ACTION POTENTIAL (13); G: 18-10**
   The structure of a neuron. The distribution of sodium, potassium and chloride ions inside and outside of typical axon. The Nernst equation. The Goldman equation. Resting potential. The Action potential. Depolarization and repolarization. Threshold of stimulation. Absolute and relative refractory period. Strength-duration curve, chronaxie and rheobase. Summation of synaptic inputs. "All or none" response.

4. **PRINCIPLES OF PHOTOMETRY (for handouts see the University or the Department web page)**
   The scotopic and photopic vision - the luminous efficiency function V(λ). Photometric quantities and their units: luminous intensity, luminous flux, illuminance, luminance. The inverse square law. Photometry: determination of the luminous intensity of a light source.

5. **SURFACE TENSION (7); G:10-13 AND MONOMOLECULAR LAYER (8)**
   Forces between molecules at a surface and in the bulk. Surface tension: definition and units. Methods of determination of the surface tension: the stalagmometer (drop count) method, and the capillary method. The Laplace law and basis of the bubble pressure method. Amphiphilic nature of molecules. Structures formed by amphiphilic molecules in solutions. Surface pressure and surface pressure-area isotherms. Estimation of molecular dimensions by analysis of the thin film parameters.

6. **LAWS OF FLOW - for handouts see the University or the Department web page, chapter (19) and G: 10-8, 10-9, 10-10, 10-11, 10-12**
   The law of continuity. Bernoulli's principle, static and dynamic pressure. The Hagen- Poiseuille law. Resistance to flow and the vascular resistance. Viscosity; definition of the coefficient of viscosity. Flow of viscous fluids. Laminar and turbulent flow. The Reynold number. Velocity of flow (the equation of continuity). Volume rate of flow. Flow of liquids in elastic vessels - the pulse wave.

7. **ELECTROMOTIVE FORCE OF A CONCENTRATION CELL: (10)**
   Chemical and electrochemical potential. Electrode potential. The concentration cell and its electromotive force. The Nernst equation. The diffusion potential and the Henderson equation. The ion mobility.

8. **ATTENUATION OF ELECTROMAGNETIC IONIZING RADIATION: (4); G: 27-3, 27-5, 27-6**
   Mechanisms of attenuation of X- and gamma-radiation (photoelectric effect, Compton effected and electron - positron pair production), The Lambert law, linear and mass attenuation coefficient. Half-value-layer. Determinations of HVL (analysis in a regular and semi-logarithmic scale)

9. **MEASUREMENTS OF DIMENSIONS OF SMALL OBJECTS BY MICROSCOPE (20); G: 25-5, 25-7**
   Index of refraction. Snell's law. Image forming - ray diagrams. Limits of resolution: resolving power; Abbe's and Rayleigh's criteria. Numerical aperture and the aperture angle. Optical system of a microscope. Magnification of a microscope. Practical magnification. Calibration procedure of the microscope eyepiece. Determination of the dimensions of micro-objects (erythrocytes) by the microscope.

You will need the ***Laboratory report forms*** which are available at the University web page and alternatively at the Department web page:http://biofizyka.ump.edu.pl/5year-DDS

SCHEDULE FOR THE LABORATORY CLASSES 2019/2020:

MONDAY 17:00 – 19:15
GROUPS A AND B

Date → / Team ↓	1 30.09 2019	2 07.10 2019	3 14.10 2019	4 21.10 2019	5 28.10 2019	6 04.11 2019	7 18.11 2019	8 25.11 2019	9 02.12 2019
1	**1** INTRODUCTORY CLASS	2	3	4	5	6	7	8	9
2		3	4	5	6	7	8	9	2
3		4	5	6	7	8	9	2	3
4		5	6	7	8	9	2	3	4

TUESDAY 18:00 – 20:15
GROUPS C AND D

Date →	1	2	3	4	5	6	7	8	9
Team ↓	01.10 2019	08.10 2019	15.10 2019	22.10 2019	29.10 2019	05.11 2019	19.11 2019	26.11 2019	03.12 2019
5	**1** INTRODUCTORY CLASS	2	3	4	5	6	7	8	9
6		3	4	5	6	7	8	9	2
7		4	5	6	7	8	9	2	3
8		5	6	7	8	9	2	3	4

SEMINAR CLASSES

There are 6 seminar classes, 120 minutes each.

Seminar classes are held at the Department of Biophysics, 6 Grunwaldzka Street (the Collegium Chemicum building).

Attendance at seminar classes is obligatory. In case of non-attendance due to illness or other personal reasons, students are advised to make up for the missed classes following the coordinator's instructions.

Students are obliged to be on time. When coming more than 15 minutes late students are not allowed to take part in classes.

Below there is the list of problems necessary for students to be acquainted with before attending each seminar class.

THE LIST OF PROBLEMS FOR THE SEMINAR CLASSES

1. PHYSICAL PROPERTIES OF BODY TISSUES AND DENTAL MATERIALS

Mechanical Properties.

The Hooke law. Stress-strain diagrams for different materials and their description and interpretation. Types of stress. The Young modulus, bulk modulus of elasticity and shear modulus of elasticity.

Rheological models of viscoelastic materials:

- the Maxwell model: the stress relaxation process and the process of creep, determination of the relaxation time and velocity of creep,
- the Kelvin-Voigt model: the elongation retardation process - determination of the retardation time.

Viscoelastic properties of the muscle tissue. The passive and active component of a muscle force.

Stress in deformed beams.

Thermal properties of materials

Specific heat and thermal capacity. Process of thermal expansion. Thermal conductivity and thermal diffusivity. Discussion of thermal mismatch.

2. BIOMECHANICS OF THE MUSCULOSKELETAL SYSTEM

Lever action of muscles and bones. Types of bone connections. Torque. Lever structure and types of levers. Levers in the body. Conditions for static equilibrium. Calculation of forces within the hip, elbow joint and temporomandibular joint. Stability of posture.
Forces on teeth, and braces.

3. BIOPHYSICS OF THE VISUAL SYSTEM

Rules of geometric optics –principles of image forming by spherical converging and diverging lenses. Optical system of the eye. Accommodation and the amplitude of accommodation. Visual defects and their classification and correction. Resolving power of the human visual system.

4. BIOPHYSICS OF THE AUDITORY SYSTEM

Physical properties of sound waves as determinants of physiological perception. The Fletcher-Munson diagram.
The mechanism of sound perception - functions of the outer, middle and inner ear:
resonance in the outer ear, the middle ear as an impedance matching system, the inner ear – the place principle of frequency discrimination.
Pure tone audiometry. Bone and air conduction.
Localization of sound sources.

5. APPLICATION OF ELECTROMAGNETIC RADIATION FROM ULTRAVIOLETY (UV) VISUAL AND INFRA-RED (IR) IN MEDICINE. PROPERTIES AND SOME APPLICATIONS OF LASER LIGHT

Characteristics of the ultraviolet, visual and infrared radiation wavebands.
Transitions between electronic, vibrational and rotational energy levels - corresponding spectra. Energy level diagrams. Radiative and non-radiative transitions. Phosphorescence, fluorescence and the energy transfer. Absorption spectra of water and some natural dyes: hemoglobin, oxyhemoglobin and melanin.
The Beer-Lambert law: absorbance, transmittance and the coefficient of absorption; related depth of penetration in tissues.
Photosensitization and the photodynamic therapy (PDT).
Some biological effects and applications of non-ionizing radiation:

- ultraviolet radiation: (tanning, treatment of psoriasis, bactericidal effect) - action spectra
- infrared radiation: thermography as a method of medical diagnostics.

Properties of laser light. Power density and fluence. Thermal and nonthermal effects of the laser light.
Classification of lasers and their use in dentistry.

6. IONIZING RADIATION IN MEDICAL SCIENCES

The nature of the corpuscular (α, β, protons, neutrons) and electromagnetic (X-rays, γ-rays) ionizing radiation. Direct and indirect interaction of the ionizing radiation with matter. Ionization density, absorbed dose, linear energy transfer (LET), the Bragg peak.
Biological effects of ionizing radiation: main stages of ionizing radiation interaction with biological systems. Factors determining biological effects of radiation: origins of biological effects and tissue-dependent radio-sensitivity. Stochastic and deterministic effects.
Nuclear Medicine Imaging - the principles of the:
- Scintigraphy method: the scintillation counter and the idea of scintigraphy method; gamma camera imaging,
- Single Photon Emission Computer Tomography (SPECT),
- Positron Emission Tomography (PET).

SCHEDULE FOR THE SEMINAR CLASSES 2019/2020

MONDAY 17:00 – 19:00

MONDAY **17:00 - 19:00**	DATE					
	09.12.2019	16.12.2019	13.01.2020	20.01.2020	27.01.2020	03.02.2020
	Topic number					
Group A room 141	1	2	3	4	5	6
Group B room 142	2	1	4	3	6	5

TUESDAY 17:30 – 19:30

TUESDAY **17:30 – 19:30**	DATE					
	10.12.2019	17.12.2019	07.01.2020	14.01.2020	21.01.2020	28.01.2020
	Topic number					
Group C room 141	1	2	3	4	5	6
Group D room 142	2	1	4	3	6	5

Integrative tests: **10.02.2020** – the Computer Center at 2 Parkowa Strret
Retake: between **24 and 29 February 2020** – the Computer Center at 2 Parkowa Street

THE EVALUATION SCHEME

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Laboratory Classes

The laboratory classes are mandatory.

Laboratory performance will be judged by the knowledge of the physical basis of the experimental methods and phenomena as well as written reports from experiments. For each laboratory class a student can get a score from 0 to 10 grade points. The score is a sum of points awarded for theoretical preparation prior to starting the experiment: fundamental knowledge of physics in the relevant area and methods to be applied (from 0 to 5 points) and for the laboratory performance and written report from the experiment (from 0 to 5 points). The final score for the laboratory classes can reach a maximum of 80 points.

Making up for missed laboratory classes.
Student can make up for the missed class on consent of the course coordinator. The absence should be explained in one week after the missed class.

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Seminar classes

The seminar classes are mandatory.

The knowledge of problems discussed at seminar classes will be judged by a 5-question quiz at the and of each seminar class. During the quiz, a student may get from 0 to 5 grade points. Furthermore, each student is invited to prepare two presentations on topics selected from the list provided and present them at the seminar class. Each presentation will be scored with additional points (0 through 5 grade points). Thus, the final score each student can reach for the seminar classes is 40 (quizzes - 30 grade points, presentations – 10 grade points).

The list of topics recommended for presentations is available at: http://biofizyka.ump.edu.pl/5year-DDS
Students are obligated to inform their teacher about their choice of subjects to be presented one week before the class.

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Points from laboratory classes and seminar classes are added. Students receive credit for the laboratory and seminar classes if the sum of the collected grade points is at least 60% of the total i.e. 72 points.
If the number of the collected grade points is less than 60% of the total, students take an integrative test covering the material of all the laboratory classes and seminars. The test can be taken two times; tests are prepared by the examination board of the Department and taken together by all the students. The threshold for passing the test is the score of 60% of the maximum score.

Getting a credit in the fall semester is essential to take the final examination.

A student who fails all the integrative tests does not obtain the credit and is not allowed to take the final examination!
A student who failed all the integrative tests have an opportunity to take the commission test before the final examination.

Students who have collected at least 70% of the total number of grade points collected during semester receive the examination bonus points. The examination bonus points are allotted as follows:

- 15% of the examination result if the sum of the collected grade points during semester equals 90% or more of the total number,
- 10% of the examination result if the sum of the collected grade points during semester is at least 80% and less than 90%,
- 5% of the examination result if the sum of the collected grade points during semester is at least 70% and less than 80%.

EXAMINATION

A written examination (single choice test) concludes the course. The test covers the material given during lectures laboratories and seminars. The examination can be repeated twice.
It is not possible to take an extra examination to elevate your grade.

The final examination dates (must be confirmed):

Date	Time
12.03.2020	8:00 – 10:15
22.03.2020	8:00 – 10:15
29.03.2020	8:30 – 10:45

If you did not pass the final examination and any of the retake examinations, the Dean could agree to a commission exam by an examination committee – see the General School Regulations

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INFORMATION

Any questions, comments or suggestions regarding the Biophysics course should be directed to the coordinator of the course Ph.D. Marek Tuliszka, Department of Biophysics, 6 Grunwaldzka Street. Additionally any other issues or details not mentioned in the above-presented rules may be still settled by the coordinator.